Koombana Bay Foreshore Excavation - Structural analysis

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CITY OF BUNBURY

Cover image: BUEE Lot 882 (WA Museum)

Contents

1.0 Introduction

This structural analysis is part of an overall report on the Koombana Bay foreshore maritime archaeological survey and test excavations carried out by the WA Museum and the City of Bunbury on 21 - 28 November 2011 (Anderson and McAllister, 2012). Three separate sites were identified during test excavation of radar anomalies detected during the ground penetrating radar survey conducted by Cardno Spectrum for the City of Bunbury. This report focuses purely on the analysis, refer to the Department of Maritime Archaeology Report No. 286, 'Koombana Bay foreshore maritime archaeological survey and test excavations, 21-28, November 2011', for historical background, excavation aims, results, discussion and recommendations.

Analysing the structural components of the sites is a vital part of identifying shipwrecks. Comparison of the dimensions of features, such as fastenings (bolts, spikes and treenails), frames and reinforcements and the stem or stern post with historical records can reveal an approximate tonnage or size of a vessel. Combining this information with wood identification can also reveal possible origins of material from the vessel.

This analysis has drawn on well known ship building references such as Charles Desmond's *Wooden Ship-building.* Desmond's book, for example, is a wealth of information on wooden ship construction of the nineteenth and early twentieth centuries including compilations of data from Lloyd's Register of Ships (see 5.1).

American registers were also vital references for comparing the scantlings and sizes of construction features. The *American Lloyd's Registry of American and Foreign Shipping* 1859, reproduced by the Nautical Research Journal provided many tables on scantlings and also detailed information on the preferred timbers used for ship construction at this time in America. Furthermore, Richard Meade's 'Scheme of Scantlings', published in *A Treatise on Naval Architecture* 1868 and also reproduced in the Nautical Research Journal, has a detailed list of scantlings for numerous aspects of vessel features, and gave the size of vessel in moulded breadth, not tonnage as Desmond and the 1859 *American Lloyd's* have. These three references have provided the basis for analysing the structure of the wreck.

2.0 BUEE Lot 882

2.1 Trench 1

2.1.1 Frame Dimensions

The dimensions of the frames from BUEE Lot 882 were compared to ‘Lloyd’s Rules and Dimensions of Material Timber’ in Charles Desmond’s 1919 publication *Wooden Ship-building* (see 5.1).

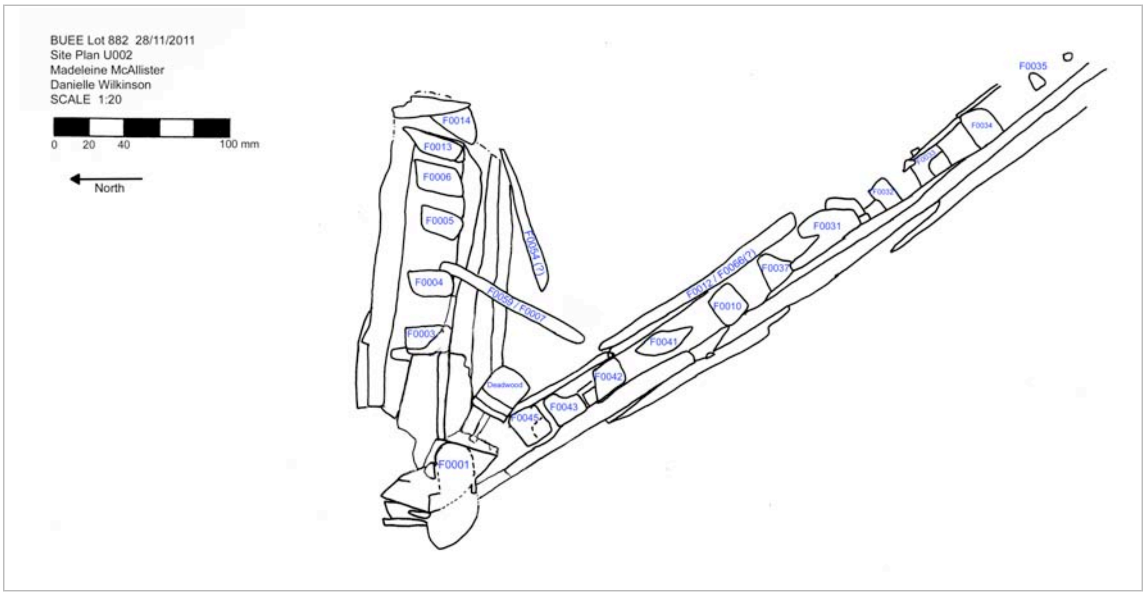

Image: Site plan of BUEE Lot 882, frames, stem and iron reinforcements labelled with feature numbers

Table: Frame dimensions and spacing
(with both metric and imperial measurements)

Frame (Feature Number)	**Siding** (Inches = “)	**Moulding** (Inches = “)	**Spacing** (Inches = “)
F0003	160 mm	220 mm	
	6.3”	8.6 “	
	6 1/8	8 1/4	
			340 mm (13.5")
F0004	140 mm	260 mm	
	5.5"	10.2 "	
	5 1/2	10 1/4	
			340 mm (13.5")
F0005	140 mm	260 mm	
	5.5 "	10.2"	
	5 1/2	10 1/4	
			220 mm (9")
F0006	150 mm	260 mm	
	5.9"	10.2 "	
	5 7/8	10 1/4	
? Feature No.?	N/A	N/A	200 mm (8")

F0045	200 mm	200 mm	
	7.9"	7.9 "	
	7 7/8	7 7/8	
			220 mm (9")
F0043	200 mm	200 mm	
	7.9"	7.9 "	
	7 7/8	7 7/8	
			240 mm (9.5")
F0042	200 mm	180 mm	
	7.9"	7.1 "	
	7 7/8	7 1/10	
F0041	N/A	N/A	340 mm (13.5")
F0010	180 mm	200 mm	500 mm (20")
	7.1 "	7.9"	
	7 1/10	7 7/8	
			340 mm (13.5")
F0032	70 mm	150 mm	
	2.75 "	5.9 "	
	2 3/4	5 7/8	
			260 mm (10.5")
F0033	200 mm	160 mm	
	7.9"	6.3"	
	7 7/8	6 1/8	
			400 mm (16")
F0034	170 mm	210 mm	
	6.7 "	8.3 "	
	6 3/4	8 1/3	

2.1.2 Frame Analysis

Knowing that the site has previously been unearthed and damaged by machinery and salvage of material, the spacing between the frames, such as on the southern side of the wreck, were affected by the site formation process and tilt of the wreck. Despite this, Lloyd’s Scantling Table (1919: 21) indicates that the frames dimensions (sidings of 5.5 inches (in) to 7.9 in) would match the dimensions of a vessel of approximately 300 to 600 tonnes (t).

It is most likely that F0006 and F0043 represent ‘filling frames’. A filling frame is a short timber that sits between two frames and reaches from the keel to the turn of the bilge (Desmond 1919: 53). This indicates that the frames that were measured are most likely 2nd or 3rd futtocks.

The *American Lloyd’s Registry of American and Foreign Shipping* (1859), states that a vessel with frame mouldings of 6 in to 10.2 in would be approximately 100 to 300 t (Nautical Research Journal 1990: 3).
Meade’s ‘Scheme of Scantlings’ suggests that sidings of frames, most likely the second or third futtock, with sidings of 5.5 in to 8 in, would give an approximate moulded breadth of 20 to 30 feet (ft) (1868: 54).

2.1.3 Stem Timber Dimensions

Due to the warped and split condition of the stem itself, the measurements taken may not be accurate and as a result the indicated tonnage of the vessel from the stem is a guide only.

Table: Dimensions of the stem timber

Stem	Siding	Moulding
	285mm	260mm
	11"	10.5"

2.1.4 Stem Timber Analysis

Under the scantling dimensions for 'Keel, Stem, Apron, and Sternpost S & M' in the Lloyd's table, the size of the stem indicates a vessel of approximately 200 to 300 t.

The 'Scheme of Scantlings' gives an estimation of moulded breadth of a vessel with this size stem siding as being 25 ft (1994: 54).

2.1.5 Hull Planking Dimensions

Table: Hull plank dimensions

Planking	Length	Width
Outside hull	N/A (extent of site)	80 mm
		3.2"
Inner Hull	N/A (extent of site)	20 mm
		1.6"

2.1.6 Hull Planking Analysis

Outer Hull Planking

Except for the garboard strake (plank next to the keel) the outer hull planking has a relatively similar thickness all the way from the garboard strake to the wales (upper deck). Therefore, the dimensions of the outer hull planking, compared to Lloyd's Scantling Table (Desmond 1919: 21) indicate a vessel of approximately 300 t.

Meade's 'Scheme of Scantlings' gives moulded breadth approximations for "Plank of Bottom", therefore, applying the dimensions from the outer planking recorded from BUEE (3.2 in) gives an approximate moulded breadth for this vessel as 25 to 30 ft (1994: 55).

Inner Planking (ceiling planking)

The fact that deadwood was present next to the stem timber, indicates that we were looking at the lower section of the vessels hull. This is important to note as the thickness of the ceiling planking may vary with respect to where it is located in the hull. For example, Desmond states that, "The bilge ceiling is of thicker material than the ceiling proper and extends until curve of bilge is passed…" (1919: 57). Fortunately Lloyd's Scantling Table only gives an estimated tonnage for a vessel with ceiling planking measuring 1.6 in to be ‘ceiling below hold beam clamp’ and estimates 100 to 200 t. All of the other possibilities for ceiling planking only start at 3 in for vessels of 100 to 200 t or larger.

2.1.7 Fastenings Dimensions

Table: Copper alloy bolts/spikes

Reg. No.	Description	Length	Thickness	Diameter	Head Diameter
5633 	1 x complete copper alloy sheathing tack w/ square shank, and 1 x possible head of tack	29 mm (1.15")	4.1 mm (0.16")	NA	10.3 mm (0.41")
5634 	Sheathing tack w/ square shank, slightly bent, copper alloy	45 mm (1.8")	3.8 mm (0.15")	NA	8.6 mm (0.35")
5653 	Copper fastening with timber attached (F0020)	185 mm (7.5")	NA	16.3 mm (0.64”)	26.8 mm (1”)
5657 	Broken Copper Alloy bolt F0052. Slightly bent near the head and missing sharp end	222 mm (8.8")	24 mm (0.95")	NA	39 mm (1.52")

2.1.8 Fastenings Analysis

2.1.8.1 Copper Alloy Fastenings

Artefact 5653, a copper alloy bolt with timber attached, was found sitting on top of the stem. If this bolt was specifically for the stem, then the diameter of approximately 1 inch gives a range of 400 to 500 t. If it is associated with the deadwood or stemson then it gives a much smaller approximation of 100 to 200 t. The *American Lloyd’s* (1859) suggests a bolt with a 0.64 in diameter is also most likely a bolt from “Butts wood ends” and represents an approximate 100 to 300 t.

Analysis of the composition of the bolt using a Scanning Electron Microscope (SEM) revealed a copper to zinc ratio of about70:30 (see 5.3) The significance of a high ratio of copper (in comparison to the more well known Muntz metal 60:40, Copper: Zinc) is expressed by McCarthy (2005: 111). Circa 1800, Paul Revere figured out how to turn pure malleable copper into ship’s fastenings. Revere’s fastenings were renown for being stronger, more resilient and not brittle due to adding a percentage of zinc, but keeping a high level of copper, resulting in strength and malleability (McCarthy 2005: 111). This safely dates this wreck to after1800.

Artefact 5657, a broken copper alloy bolt, has a diameter of 24 mm. According to the bolt dimensions from Lloyd's Fastenings Table (Desmond 1919: 21), this would place the vessel in the range of 250 to 450 t. The composition revealed by the SEM analysis showed the bolt had a copper to zinc ratio of 60:37, with a small percentage of lead (approximately 2%) (see 5.3). An early 20^{th} century metallurgist Vickers (1923:425) stated that the range of the copper to zinc ratio for Muntz metal was only 60-62 parts copper to 40-38 parts zinc. Therefore, the fastening falls only minutely out of the range of Muntz metal. However, Alfred Muntz patented another version of this alloy in 1846; in this alloy a small percentage of lead was added to increase malleability of the alloy (Anderson 2010: 8). It is likely that this presence of lead indicates that the fastening dates to after 1846.

As for the tacks found on site, little can be revealed from noting and analysing the dimensions, as Falconer has stated copper nails were "made of mixed metal of various lengths and sizes; they have a flat round head, with a square shank about one inch and a half long." (McCarthy 2005: 174-175). The tacks measured from BUEE ranged from 1 in to nearly 2 in long. The composition of artefact 5634 was analysed with the SEM and revealed a copper to zinc ratio of 80:20 (see 5.3) Similar to artefact 5653, the high ratio of copper is linked to the need for strength combined with malleability and therefore dates to after 1800.

2.1.8.2 Copper Alloy Sheathing

Copper sheathing is a useful indicator for dating wrecks. Sheathing of vessels came about in an attempt to stop the destructive wood boring shipworm (*teredo navalis*) and fouling occurring so quickly on wooden vessels (Bingeman et. Al 200: 218). Many different forms of sheathing exist such as early examples of wood and lead. As McCarthy (2005: 102) has noted, recent studies of sheathing in have revealed reports of Chinese junks using sheathing as early as 1740. The composition of copper sheathing is significant to dating because many different forms of mixed metals were created to try and alleviate the galvanic action created when copper and iron came into contact underwater (McCarthy 2005: 103).

Image: Copper sheathing fragment (WA Museum)

In 1832, a patent bought by George Frederick Muntz for a copper-zinc alloy with a composition of 'lose to'60% copper and 40% zinc (Bingeman et. Al 2000: 224). Whilst it is certain that mixes of 60:40 copper alloys were being used before Muntz took out the patent, it is a useful indicator to narrowing down the possible date for the wreck.

Analysis of the sheathing (artefact 5635) using a Scanning Electron Microscope (SEM) showed that the sheathing had a composition of 61.62% copper and 37.25% zinc and 1.13% lead. (see 5.3) Therefore, the sheathing is similar to the artefact 5657; it is most likely a result of the second Muntz patent and dates to after the 1846.
A previous metallographic analysis of a copper alloy bolt in an unidentified timber from Glenfield's Beach, Western Australia (Anderson 2010), also revealed a different composition of copper to zinc. The composition of this bolt was 63% copper, 32% zinc and 0.7% lead (Anderson 2010: 8). The presence of lead in the copper alloy can be related to a second patent that Muntz took out in 1846, this included a small amount of lead to improve malleability and reduce copper oxidation (Anderson 2010: 9). This is another possibility that could explain the presence of lead in the Bunbury artefacts. If this is likely then it is a good dating means, placing the artefacts to post 1846.

2.1.8.3 <u>Iron fastenings</u>

Table: iron bolt dimensions

Reg. No.	Description	Length	Thickness	Diameter	Head Diameter
5639 	Concretion, possible bolt head. Has Impression of square spike.	50 mm (2")	NA	NA	NA

5641 	Iron fastening	101.8 mm (4")	12.7 mm (0.5")	NA	NA

Due to the high level of corrosion of the iron bolts and spikes found, undertaking analysis similar to the copper alloys (such as SEM) would be inconclusive. Furthermore, the amount of concretion and corrosion would cause any measurements of dimension to be misleading.

2.1.8.4 Iron Reinforcements (crutches)

No actual iron knees were found during the excavation, however, iron breast-hooks were revealed inside the hull. These breast-hooks were located in the bow area of vessels and replaced the large, sturdy wooden breast-hooks, at a transitional period from completely wooden ships to composite ships (Stammers, 2001: 116). In essence these iron reinforcements were specialised knees for the bow (See figure below).

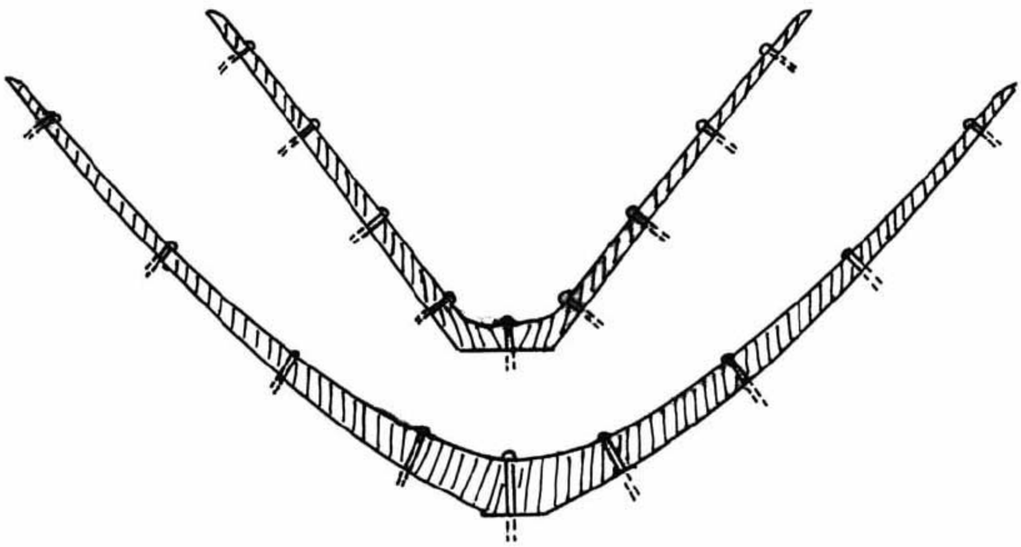

Image: Iron breast-hooks (Stammers, 2001: 20). NOTE: The top feature represents an iron crutch, similar to those found in BUEE Lot 882.

Table: Iron breast-hook dimensions

	Length	Width
Iron crutch	100 cm = 3’ 3.4” 140 cm = 4’ 3.4”	4” at the ends 7” in the middle

Iron crutches analysis

Stammers analysis of the use of iron breast-hooks and crutches relates to the British shipbuilding industry and the need for strength as vessels grew larger (2001: 120). They were included in the wooden ship *Jhelum* built 1849, *Jhelum* also included iron knees (Stammers, 2001: 120). This could indicate the presence of iron knees at this site, although none were uncovered. As for dating the vessel, iron crutches were in use from as early as 1813 in Britain (Stammers, 2001: 120).

2.1.8.5 Treenails

Table: Treenail dimensions

Reg. No.	Description	Length	Thickness	Diameter	Head Diameter
5642 	Tree nail, wood	84 mm (3.3")	NA	32.8 mm (1.3")	NA
5643 	Peg or tree nail, broken	120 mm (4.7")	NA	31.5 mm (1.25")	NA
5644 	Peg or tree nail + 1 timber fragment	145 mm (5.7")	NA	32.9 mm (1.3")	NA
5660 	Ship's timber w/ evidence of tree nail features, also w/ bolts and tree nails embedded.	165 mm (6.5")	NA	33 mm (1.3")	NA
5664 	Ship's timber w/ tree nails and tree nail features; and a distinct angel feature of possibly an iron breast.	NA	NA	30 mm (1.2"), 32 mm (1.25"), 38 mm (1.5")	NA

Generally, the treenails from BUEE Lot 882 are approximately 1.3" (1 1/3). Comparison of these treenails with 'Lloyd's Fastening Dimensions: Sizes of Bolts, Pintles of Rudder, and Treenails' indicates they are from a vessel of approximately 350 to 450 t.

The *American Lloyd's* gives an approximation of the tonnage of vessels using treenails. In this case, a treenail of 1.3" can be found in a vessel ranging from 300 to 800 t (1989: 219).

2.1.9 Wood Identification

Wood samples were taken from 10 different features on site. The identification of this wood will reveal which country it is originally from and be a useful aid in narrowing down the list of possible vessel identities.

The wood identification indicates that the timber in the vessel generally has either European of Central to North American origins (see 5.2). This indicates that the vessel was built in the northern hemisphere. The presence of a eucalypt species native to Australia indicates that this vessel had probably undertaken repairs whilst in an Australian port or traded for Australian timber to use at a later stage in case of repairs.

2.1.10 Conclusion

The dimensions recorded for this wreck give a wide range of the possible tonnage for this vessel, between 100 to 800 t. It is likely that the vessel tonnage sits in the middle of this range, as the majority of sizes fell between 200 to 400 t. The approximate moulded breadth of the vessel is 25 to 30 ft.

The analysis of copper alloy fastenings recovered from the wreck have revealed very specific ratios for the elements in the alloys and further study may reveal more specific information regarding their fabrication. The presence of a small percentage of lead in the copper alloy sheathing indicates that it dates to post 1846, in conjunction with the second copper alloy metal patent taken out by Alfred Muntz.
Wood identifications indicate that the origin of the vessel is either European or North American and it was constructed in the northern hemisphere.

3.0 BUEW Lot 881 - Trench 1

3.1.1 Introduction

The structural features recorded in Trench 1 of BUEW Lot 882 most likely represent the upper side of a vessel that has fallen onto its outside hull as the site degraded.

The iron knees are very similar to that of the *Solglyt,* an 875 t barque built in Norway in 1888. Wrecked in Koombana Bay 1901, *Solglyt* was uncovered during excavation of the southern "cut", now Koombana Channel in 1973 (McCarthy 1982: 9), as it was not protected by legislation at this time the wreck was broken up and moved out of the way. However, it is recorded that the owners of the wreck were ordered to move it from its wrecking place (MA File 405/71) and only the port side was found in 1973. This present the highly likely possibility that there are substantial remains of *Solglyt* still buried beneath the beach.

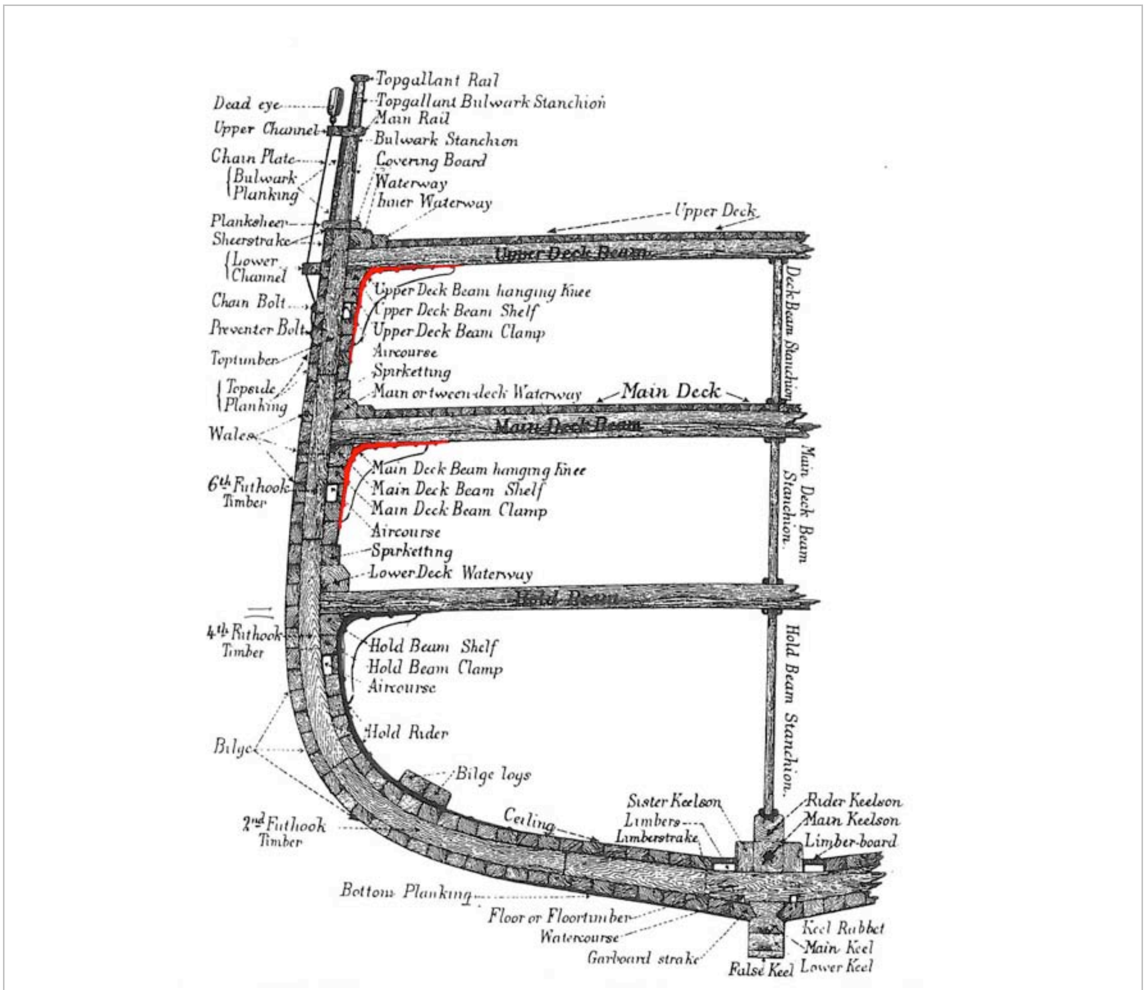

Image: 'Cross section of ship showing construction details, marked for identification (Desmond, 1919: 46). Note: Deck knees are shown in red. The iron knees that were recorded represent deck or knee riders.

Image: Upper port hull section of *Solglyt,* found in 1973 before being removed. (NOTE: the iron knees)

Image: Wreck features located in Trench 1. Lot 881 (P. Baker)

The similarity between the features of the *Solglyt* and BUEW are a useful indication of the age of the unidentified wreck, it is likely that the BUEW site is of the same period. Analysis of the structural remains will give an approximation of the tonnage of the wreck.

3.1.2 Knee Rider Dimensions

Table: Knee Dimensions

Feature No.	Siding	Moulding	Length	Spacing	Angle of knee
F0005	140 mm	50 mm	1300 mm	1400-1360 mm	50
	5.5"	2"	51"	55" - 53.5"	
			4'3"	4'6"	
F0023	140 mm	50-75 mm	2380 mm	1200-1300 mm	NA
	5.5"	2" - 3"	94"	51" - 51.2"	
			7'10"	4'3"	
F0024	140 mm	NA	3100 mm	1240-1380 mm	NA
	5.5"		122"	49" - 54"	
			10'2"	4'4"	
F0013	100-140 mm	NA	2300 mm	NA	NA
	3.9" - 5.5"		90"		
			7'6"		

3.1.3 Knee Rider Analysis

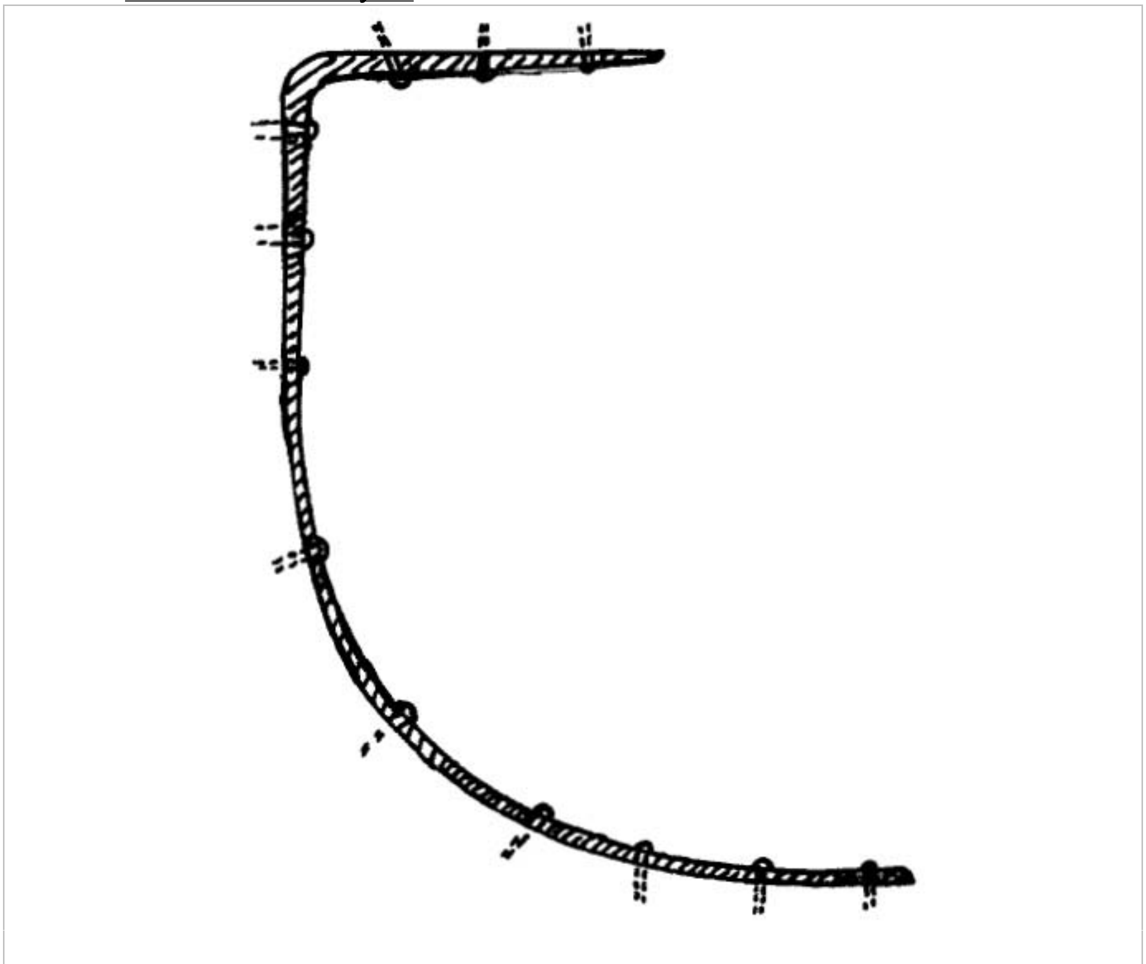

Image: Knee rider (Stammers 2001: 118)

The image above is from an article by Stammers (2001), Stammers' research indicated that the knee rider was developed to support the hold beams and to strengthen the lower parts of the hull, the lower arm was considerably long. This is similar to the iron reinforcements found in BUEW with the similar length of both arms, and a similar ratio of bolt fastenings. Furthermore, he states that they were "…used extensively in British-built vessels well into the 20th century and was recorded, for example, in the schooner *Emily Barrett* of 1913" (2001: 119).
However, it should be noted that the use of iron knee riders, such as these, have been recorded in vessels dating much earlier. Some examples include, *Vicar of Bray* (1841), *Jhelum* (1841) and *Camilla* (1834) (Moss, 2007: 86-7).

3.1.4 Frame Dimensions

Table: Fame dimensions

	Siding	Moulding
Frame (from sondage)	220 mm (8.7")	160 mm (6.3")

3.1.5 Frame Analysis

The frame recorded in the sondage (1 x 1 m investigation trench) could be either a second or third futtock or top timbers. If it is a second or third futtock then it falls into the approximate vessel size of 300 to 400 t. However, if the frame timbers represent top timbers then the vessel size was approximately 600 to 700 t.
The 'Scheme of Scantlings' gives a moulded breadth of 35 ft for a floor or first futtock with a siding of 8.7 in, whilst it gives a moulded breadth of 40 ft for a top-timber (1994: 54).

3.1.6 Fastening Dimensions

Table 1: Fastenings dimensions

Reg. No.	**Description**	**Length**	**Thickness**	**Diameter**	**Head Diameter**
F0024 	Metal bolt with timber attached at one end	115 mm (4.5")	NA	9.8 - 10 mm (0.4")	NA
F0054/T1 	Iron concreted/corroded	128 mm (5")	10.7 - 11.3 mm (0.5")	NA	25.3 mm (1")
F0052/T1	2 x iron spikes squared (concreted)	a) 140 mm (5.5")	NA	NA	NA

		b) 150 mm (6”)			
F0004/T1/X13 	Copper bolt (broken)	200 mm (7.9”)	NA	20.2 mm (0.8")	28 mm (1.14")

Table 2: Fasteners measured from the knee riders on site.

F0005 - Bolts from south	**Diameter**	**Spacing**
	20 mm (0.8") 13/16	NA
	20 mm (0.8") 13/16	360 mm (14.2")
	30 mm (1.2") 5/4 or 1 1/4	500 mm (19.7")
F0023 - bolts from south		
	20 mm (0.8") 13/16	NA
	30 mm (1.2") 5/4 or 1 1/4	240 mm (9.5")
	20 mm (0.8") 13/16	500 mm (19.7")
F0024 - bolts from south		
	20 mm (0.8") 13/16	NA
	20 mm (0.8") 13/16	820 mm (32.3")
	20 mm (0.8") 13/16	420 mm (16.5")
	20 mm (0.8") 13/16	400 mm (15.8")
	20 mm (0.8") 13/16	400 mm (15.8")
	20 mm (0.8") 13/16	400 mm (15.8")
F0013 - bolts from south		
	20 mm (0.8") 13/16	NA
	NA corroded	400 mm (15.8")
	20 mm (0.8") 13/16	400 mm (15.8")
	NA corroded	400 mm (15.8")
	20 mm (0.8") 13/16	400 mm (15.8")

3.1.7 Fastening Analysis

Comparison of the fastenings on the riders (see Table 2.) with Desmond’s table based on Lloyd’s Fastening Dimensions (1919: 21), shows that the expected tonnage of this vessel is anywhere between 250 to 700 t.

The results of comparing these bolts to the scantlings given in the ‘Scheme of Scantlings’ gives a moulded breadth of a vessel with upper deck bolt diameter of 40 to 50 ft (1994: 54)

Like the iron fastenings recovered from BUEE Lot 882, the high level of corrosion meant that further analysis, such as SEM, would have been inconclusive.

3.1.8 Planking Dimensions

Table: planking dimensions from sondage in trench 1 (X12/W12) below F0013

Feature	Siding	Moulding
Outer Planking	NA	NA
Inner Planking	150 mm (6")	100 mm (3.9”)

3.1.9 Planking Analysis

Comparison of the inner planking with Desmond’s table ‘Lloyd’s Planking Table’ (1919:21) indicates an approximate size of 500 to 700 t. The ‘Scheme of Scantlings’ gives the vessel a moulded breadth of 50 feet with ceiling (inner) planking being 3.9 in thick (1994:54).

3.1.10 Wood Identification

All of the samples from Trench 1 had the same type of wood. They were all pine of the red deal type. These pines are native to Europe (Scot’s Pine (*Pinus sylvestris* L.) & Austrian/Corsican pine (*P. nigra Arnold*)), North America (red pine (*P. resinosa Ait*.)) and Asia (see 5.2).

The wood identification is therefore inconclusive as the range of pines is too broad to pinpoint a specific country of origin.

3.1.11 Conclusion

The vessel uncovered in Trench 1 is very similar to wrecks from the late nineteenth to early twentieth century. Analysis of the structural features of the site has revealed a vessel of a possibly range of approximately 300-700 tonnes, although the average tonnage suggest a vessel of 500 to 700 t is more likely. The moulded breadth of the vessel was most likely 40 to 50 ft.

The wood identification revealed pine native to Europe, North America and Asia. Therefore the vessel originated in the northern hemisphere.

3.2 BUEW Lot 881 - Trench 2

The structure uncovered in Trench 2 of BUEW Lot 881 was very different to the structure from Trench 1. It is possible that it is the remains of the deck of a ship. This theory was put forward after unearthing a lead crystal deck light. Deck lights are glass prism installed in ships decks to filter light through to the lower decks.

3.2.1 Fastening Dimensions

Table: Fastenings from site with dimensions.

Reg. No.	Description	Length	Diameter	Head Diameter
F0094/T2 	Iron (?) corroded bolt	160 mm (6.3")	NA	NA
F0093/T2 	Iron (?) corroded bolt	165 mm (6.5")	NA	20.5 mm (0.85")
F0092/T2 	iron spike (?) concreted	130 mm (5.1")	10 mm (0.33-0.36")	10 mm (0.36-0.38")
F0069/T2/S12 	2 x iron (?) spikes concreted	a)165 mm (6.5") b)148 mm (5.8")	a)8.6 - 8.4 mm (0.33-0.31") b)7.8 mm - 7.6 mm (0.3-0.29")	NA

The image below shows where the bolts and treenails recorded were located in the site. (All measurements of fastenings in the following tables)

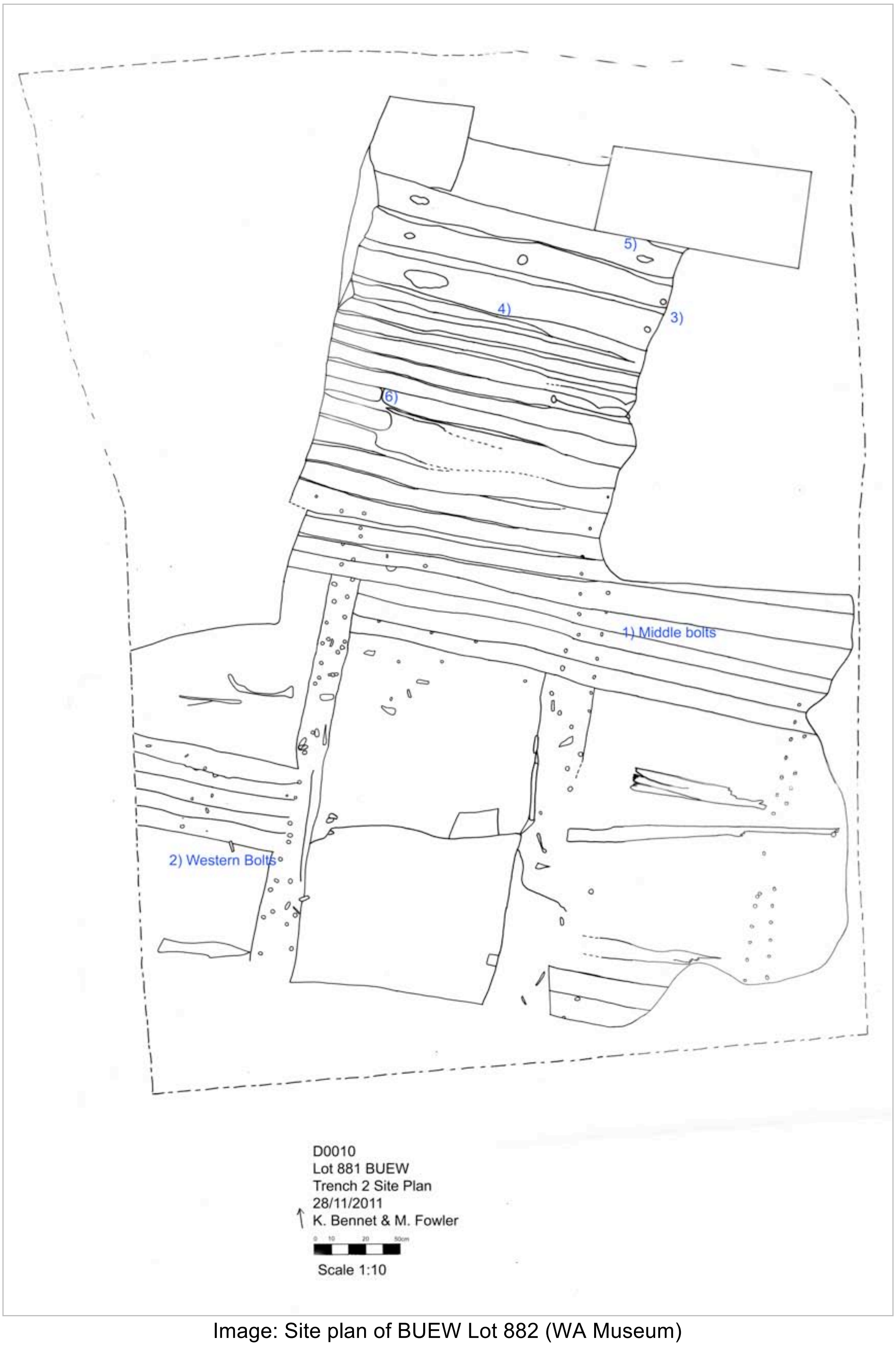

Image: Site plan of BUEW Lot 882 (WA Museum)

Table: fastening dimensions measured in-situ

Fastenings	**Diameter**	**Distance between centrepoints (N-S)**	**Distance between centrepoints (E-W)**	**Distance between**
1. Middle bolts (iron)	25 mm (1")	110 mm (4.4")	160 mm (6.3")	NA
2. Western bolts (iron)	25 mm (1")	130 mm (5.1")	105 mm (4.2")	NA
3. iron bolts	25 mm (1")	NA	NA	210 mm (8.3")
4. bolts	40 mm (1.6")	NA	NA	740 mm (29.3")
5. treenails	45 mm (1.8")	NA	NA	450 mm (17.8")
6. iron bolts and treenails	25 mm and 20 mm (1")	NA	NA	60 mm (2.7") and 50 mm (2")

3.2.2 Fastening Analysis

Comparison of the iron bolts diameters to 'Lloyd's Fastening Dimensions' table (Desmond 1919: 21) suggest that a vessel with deck bolts for either upper deck hanging knees measuring 1 in to 1.6 in would give a tonnage of anywhere between 500 to 1350 t.

The state of corrosion for the iron fastenings recovered meant that further analysis of the composition of materials would be inconclusive.

The dimensions of the treenails (1 in to 1.8 in) in comparison to the same Lloyd's Fastening Dimensions table gives an approximate vessel tonnage of 100 to 1350 t. Comparison of the treenail dimensions given by the *American Lloyd's* scantlings suggests a tonnage of anywhere from 100 to 2000 t (1989: 219).

3.2.3 Deck Waterway

A feature was uncovered in the north-west corner of the trench after a small sondage was set up to investigate the structure further. This feature most likely represents the 'deck waterway' or edge of the deck (see figure below)

Figure: Deck beam and waterway (Alice Beale/ WA Museum)

Dimensions of Deck beam

	Siding	**Moulding**
Deck beam	30 c m 11.8” 11 3/4	25 c m 9.8” 9 3/4

3.2.4 Deck Beam Analysis

The “Scheme of Scantlings” gives a breadth of a vessel with a main deck beam with a siding of 11 ¾ as being 35 to 40 ft in moulded breadth.

3.2.5 Wood Identification

All of the wood samples collected from Trench 2 revealed they were a red deal pine native to Europe (Scot’s Pine (*Pinus sylvestris* L.) & Austrian/Corsican pine (*P. nigra Arnold*)), North America (red pine (*P. resinosa Ait*.)) and Asia. (see 5.2).

As a result the wood identification indicates a vessel that originated in the northern hemisphere.

3.2.6 Conclusion

The remains uncovered in Trench 2 are most likely related to a vessel of approximately 100 to 2000 t. However, structural analysis of the iron fastenings indicates a vessel of approximately 500 to 700 t. The presence of a ‘deck light’ in the structure indicates that it is possibly part of a top deck structure for a vessel. This is also reinforced by the presence of the deck waterway and deck beam features. The deck dimensions of the deck beam suggest the vessel had a moulded breadth of 35 to 40 ft.
The wood identification revealed all timbers were pine of the red deal type, native to Europe, North America and Asia. Therefore the wood identification indicated a vessel of northern hemisphere origins.

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5.0 Appendices

5.1 Lloyd's Tables

(Desmond, C. 1919, *Wooden Ship-Building,* Vestal Press Ltd, New York, pp.20-21.

1. Lloyd's Scantling Table

TABLE 3B—LLOYD'S SCANTLING TABLE

Minimum Dimensions in Inches, of Timbers, Keelson, Keel, Planking, Etc.

TONNAGE	100	200	300	400	500	600	700	800	900	1050	1150	1250	1350	1500	1750	2000
Timber and Space—Inches	19	21½	24¼	27¼	30	30½	31¼	31¾	32½	33¼	33½	33½	33¾	34	34½	35
Floors, S & M at Keelson, if Squared	7½	8¾	10¼	11¾	13	13¼	13½	13¾	14	14½	14¾	15	15¼	15¼	15½	15¾
Double Floors, S & M at Keelson, if Squared	6½	7¾	9¼	10½	12	12¼	12½	12¾	13	13½	13¾	14	14¼	14¼	14½	14¾
1st Futtocks, S & M at Floorheads, if Squared	6½	7¾	8¾	10	11	11½	11¾	12¼	12½	13¼	13½	13¾	14¼	14¼	14½	14¾
2nd Futtocks, Sided, if Squared	6	7	8	9	10	10½	10¾	11¼	11½	12¼	12½	12¾	13¼	13¼	13½	13¾
3rd Futtocks, Sided, if Squared	5¾	6½	7¼	8¼	9	9½	9¾	10¼	10½	11¼	11½	11¾	12¼	12¼	12½	12¾
Top Timbers (Short), Sided, if Squared	.....	.....	.....	.....	9	9¼	9½	9½	9¾	10	10¼	10½	10¾	10¾	11	11¼
Top Timbers, Moulded at Heads, if Squared	4½	5	5¼	5¾	6	6¼	6½	6¾	7	7¼	7½	7¾	8½	8½	8¾	9
Breast Hooks and Wing Transom, S & M in Middle	8½	9¾	10¾	12	13	13¼	13½	13¾	14	14½	14¾	15	15¼	15¼	15½	16
Keel, Stem, Apron, and Sternpost, S & M	9	10¾	11¾	13	14	14¼	14½	14¾	15	15½	15¾	16	16¼	16½	16¾	17
Keelson, S & M	10	11¾	12¾	14	15	15¼	15½	15¾	16	16½	16¾	17	17¼	17½	17¾	18
Wales	3½	4¼	4½	4¾	5	5	5¼	5½	5½	6	6	6	6¼	6½	6¾	7
(e) Bottom Plank, from Keel to Wales	2¼	2¾	3¼	3¾	4	4	4	4¼	4¼	4½	4½	4½	4½	4½	4¾	5
Sheer Strakes, Top Sides, Upper Deck Clamp (No Shelf); Lower Deck, Clamp with Shelf	2½	3¼	3½	3¾	4	4	4¼	4¼	4¼	4½	4¾	4¾	5	5¼	5½	5½
Ceiling Below Hold Beam Clamp	1¾	2¼	2¾	2¾	3	3¼	3¼	3½	3½	3¾	3¾	4	4	4¼	4½	4½
Waterway:																
Hardwood	4	5	5½	6	6½	6½	7	7	7½	7½	7½	8	8	8½	8½	9
Fir	4½	5½	6½	7	8	8	8½	8½	9	9	9	9½	9½	9½	9½	10
Ceiling Betwixt Decks	1¾	2	2¼	2½	2½	2½	2¾	2¾	2¾	2¾	3	3	3	3¼	3½	3½
Bilge Plank, Inside, Thick Strakes and Limber Strake	3	3¾	4	4¼	4½	4½	4½	4¾	5	5½	5¾	6	6¼	6¼	6½	7
Lower Deck Clamp (No Shelf) and Spirketting	3	3¼	3¾	4	4½	4¾	4¾	4¾	5	5¼	5¼	5½	5½	5½	5¾	6
Upper Deck Clamp (With Shelf)	2¼	2½	2¾	2¾	3	3¼	3¼	3½	3½	3¾	3¾	4	4	4¼	4½	5
Planksheer	2¼	2¾	3¼	3¾	4	4	4	4	4	4	4	4	4	4¼	4½	5
Flat of Upper Deck	2½	3	3	3	3½	3½	3½	3½	4	4	4	4	4	4	4	4
Scarphs of Keelson Without Rider	4'9"	5'3"	5'10"	6'6"	7'	7'	7'	7'3"	7'3"	7'6"	7'9"	7'9"	8'	8'	8'	8'
Scarphs, where Rider Keelson is added, also Scarphs of Keel	4'3"	4'9"	5'2"	5'6"	6'	6'	6'	6'3"	6'3"	6'6"	6'9"	6'9"	7'	7'	7'	7'
Main Piece of Windlass—Inches	14	15	15	16	17	18	19	21	22	23	23	24	24	25	25	27

2. Lloyd's Planking Table

TABLE 3C—LLOYD'S PLANKING TABLE

For the Thickness of Inside Plank, and in the Construction of Ships in the British North American Colonies and All Fir Ships Wherever Built

TONNAGE—Tons	100	200	300	400	500	600	700	800	900	1050	1150	1250
Thick Waterway—Inches.	5¼	6	6½	7½	8	8½	9	9½	10	11	11½	12
Spirketting.	3	3¼	3¾	4	4½	4¾	4¾	5	5½	5¾	6	6¼
Ceiling Below Hold Beam Clamp and Between Decks.	2	2½	3	3½	3¾	4	4¼	4½	4¾	5	5¼	5½
Bilge Plank (inside).	3	3¾	4¼	4¾	5½	6½	7	8	9	10½	11½	12
Thickstuff Over Long and Short Floorheads and Limber Strakes.	2¾	3¼	3½	4	4½	5	5½	6	6½	7	7¼	7½
Main Keelson (Rider Keelsons may be two-thirds that of main ditto).	10	11¾	12¾	14	15	15½	15½	15¾	16	16½	16¾	17

3. Lloyd's Fastening Table

TABLE 3D—LLOYD'S FASTENING DIMENSIONS

Sizes of Bolts, Pintles of Rudder, and Treenails

TONNAGE	100	150	200	250	300	350	400	450	5 0	700	900	1350
Heel-Knee, Stemson and Deadwood Bolts ....Inches	15/16	1	1	1 1/16	1 2/16	1 2/16	1 3/16	1 4/16	1 4/16	1 5/16	1 6/16	1 8/16
Bolts in Sister Keelsons, Scarphs of Keel (a), Breast Hooks, Pointers, Crutches, Riders, Knees to Hold or Lower Deck Beams, Shelf, Clamp and Waterway Throat Bolts of Upper Deck Hanging Knees.	12/16	12/16	12/16	13/16	14/16	14/16	15/16	15/16	1	1 2/16	1 3/16	1 4/16
Keelson Bolts, Throats of Transoms, Throats of Breast Hooks, and Throats of Hanging Knees to Hold or Lower Deck Beams.	13/16	14/16	14/16	15/16	1	1	1 1/16	1 2/16	1 2/16	1 3/16	1 4/16	1 6/16
Bilge, Limber Strake, and Through Butt Bolts.	10/16	10/16	11/16	11/16	12/16	12/16	13/16	13/16	14/16	14/16	15/16	1
Other Butt Bolts.	10/16	10/16	10/16	11/16	11/16	11/16	12/16	12/16	12/16	12/16	13/16	14/16
Bolts through Heels of Cant Timbers, Bolts of Upper Deck Waterway, Shelf and Clamp, Arms of Hanging and Lodging Knees.	11/16	11/16	11/16	12/16	13/16	13/16	14/16	14/16	14/16	15/16	1	1 2/16
Pintles of Rudder.	2	2	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	3	3	3 1/4	3 1/2	3 1/2
Hardwood Treenails.	1	1	1 1/8	1 1/8	1 1/8	1 1/4	1 1/4	1 1/4	1 3/8	1 3/8	1 3/8	1 1/2

(a) Number of Bolts in Scarphs of Keel:
In ships of 150 tons and under............6 Bolts
" " above 150 tons and under 500 tons. 7 Bolts
" " 500 tons and above..............8 Bolts
} These bolts to be of Copper or Yellow Metal in all cases

N.B. Bolts to be through and clenched, and to be of good quality, well made with suitable heads and be tightly driven.

5.2 Wood Identification

WOOD IDENTIFICATION

Ian Godfrey

29 December 2012

Job No. - 11/96
Bunbury Excavation East/Lot 882 (Superpit)
BUEE/882

Wood identifications:

All wood samples were polished to a 1200 grit finish before low power microscopic examination of the end grain features. Sections were taken from the radial longitudinal surfaces of any softwood samples for high power microscopic examination. Summaries of all examined timbers are given below.

BUEE/882/WCORE5
Examination of the end grain revealed the following features - rays of 2 distinct widths with the larger rays wider than the pores, distinct growth rings, ring porous arrangement and abundant tyloses present in the pores. The sample is a white oak (Quercus species). White oaks are native to Europe and North America.

BUEE/882/WCORE3, BUEE/882/WCORE6, BUEE/882/WCORE7 and BUEE/882/WCORE8 were also white oak. WCORE3 was quite degraded, the inner parts of WCORE7 were in very good condition and WCORE8 was in very good condition.

BUEE/882/WCORE9 - the sample is a softwood with an abrupt transition between the early and the latewood. Resin canals are present. Highly dentate ray tracheids were clearly visible on the radial longitudinal surfaces but it was difficult to detect the nature of the cross field pits present in the ray parenchyma. Although initial observations were not conclusive, eventually the presence of small pinoid pits (3-4 per crossfield) were detected. The sample is therefore a pine of the pitch pine type, examples of which include longleaf pine (Pinus palustris Mill. - southern North America), slash pine (P. caribaea Morelet - Central America) and loblolly pine (P. taeda L. - so0thern and south-eastern North America). This sample is therefore of North or Central American origin.

BUEE/882/WCORE10 - sample is a hardwood with the the following features: rays are narrower than the pores; soft tissue surrounds the pores; the pores are moderately numerous, are small to intermediate in size, predominantly solitary and in an oblique arrangement; tyloses are abundant. The sample is clearly a Eucalyptus species, native to Australia.

Job No. - 11/95
Bunbury Excavation West/Lot 881/Trench 1
BUEW/881/T1

Wood identifications:

All wood samples were polished to a 1200 grit finish before low power microscopic examination of the end grain features. Sections were taken from the radial longitudinal surfaces of any softwood samples for high power microscopic examination. Summaries of all examined timbers are given below.

BUEW/881/T1/W12/U0002/F0082 - the end grain features were too distorted and no useful diagnostic features could be discerned by microscopic examination. The wood appeared to be a hardwood but that is all that could be concluded.

BUEW/881/T1/SX12/U0002/F0078 - the sample is a softwood with an abrupt transition between the dense latewood and the less dense early wood. Resin canals were present.
Dentate ray tracheids and smooth-walled ray parenchyma with large simple cross field pits were visible on the radial longitudinal surface.
The sample is a pine of the red deal type, examples of which include Scots pine (Pinus sylvestris L. - Europe), red pine (P. resinosa Ait. - eastern North America) and Austrian/Corsican pine (P. nigra Arnold - Europe). Pines of this group are native to Europe, North America and Asia.

BUEW/881/T1/X12/U0002/F0079 - this is also a softwood. The transition between the early and the latewood was more gradual than with sample F0078 but all other features were identical with F0078. This sample is therefore also a pine of the red deal type.

BUEW/881/T1/X13/U0001/F0052 - this sample is as for F0078 and F0079, although the features of the ray tracheids were less clear and only discerned with difficulty. In places there were 2 simple pinoid pits per cross field. A number of sections were taken to confirm the presence of dentate ray tracheids. Sample is a pine of the red deal type.

These wood identifications do not allow a provenance to be given to the wood samples as pines of the red deal type are native to Europe, North America and Asia.

Job No. - 11/97
Bunbury Excavation West/Lot 881/Trench 2
BUEW/881/T2

Wood identifications:

All wood samples were polished to a 1200 grit finish before low power microscopic examination of the end grain features. Sections were taken from the radial longitudinal surfaces of any softwood samples for high power microscopic examination. Summaries of all examined timbers are given below.

BUEW/881/T2/WCORE1 - the sample is a softwood with an abrupt transition between the early and the latewood. Resin canals are present. Dentate ray tracheids

and large pinoid simple pits in the ray parenchyma were observed in a radial longitudinal section.
The sample is a pine of the red deal type, examples of which include Scots pine (Pinus sylvestris L. - Europe), red pine (P. resinosa Ait. - eastern North America) and Austrian/Corsican pine (P. nigra Arnold - Europe). Pines of this group are native to Europe, North America and Asia.

BUEW/881/T2/WCORE2, BUEW/881/T2/WCORE3, BUEW/881/T2/WCORE4, BUEW/881/T2/WCORE5 and BUEW/881/T2/WCORE7 had identical microscopic features as BUEW/881/T2/WCORE1 and are therefore also pines of the red deal type. The transition between the earlywood and the latewood was a little more gradual for sample BUEW/881/T2/WCORE3 than for the other samples.

The provenance of these wood samples cannot be conclusively assigned as red deal pines are native to Europe, North America and Asia.

5.3 SEM Data

Artefact BUEE 5634 - sheathing tack				
Acquisition Time:15:11:56	Date: 8-Mar-2012			
kV:30.00	Tilt: 0.00	Take-off:35.47	Tc:2.5	
Detector Type :SUTW-Sapphire	Resolution :168.00	Lsec :59		
EDAX ZAF Quantification	Standardless			
Element Normalized				
SEC Table : Default				
Element	Wt %	At %		
CuK	79.68	80.14		
ZnK	20.32	19.86		
Total	100	100		
Element	Net Inte.	Bkgd Inte.	Inte. Error	P/B
CuK	6708.39	152.8	0.16	43.9
ZnK	1496.88	137.77	0.36	10.86
Artefact BUEE 5635 - sheathing				
Acquisition Time:15:16:27	Date: 8-Mar-2012			
kV:30.00	Tilt: 0.00	Take-off:34.44	Tc:2.5	
Detector Type :SUTW-Sapphire	Resolution :168.00	Lsec :60		
EDAX ZAF Quantification	Standardless			
Element Normalized				
SEC Table : Default				
Element	Wt %	At %		
CuK	59.47	61.62		
ZnK	36.99	37.25		
PbL	3.54	1.13		
Total	100	100		
Element	Net Inte.	Bkgd Inte.	Inte. Error	P/B
CuK	4669.57	116.72	0.19	40.01
ZnK	2548.7	100.13	0.27	25.45
PbL	54.1	74.2	3.4	0.73
Artefact BUEE 5653 - round bolt				
Acquisition Time:15:23:42	Date: 8-Mar-2012			
kV:30.00	Tilt: 0.00	Take-off:35.50	Tc:2.5	

Detector Type :SUTW-Sapphire	Resolution :168.00	Lsec :60		
EDAX ZAF Quantification	Standardless			
Element Normalized				
SEC Table : Default				
Element	Wt %	At %		
CuK	69.96	70.55		
ZnK	30.04	29.45		
Total	100	100		
Element	Net Inte.	Bkgd Inte.	Inte. Error	P/B
CuK	5777.95	148.83	0.17	38.82
ZnK	2171.35	130.4	0.29	16.65
Artefact BUEE 5657 - round bolt				
Acquisition Time:15:57:45	Date: 8-Mar-2012			
kV:30.00	Tilt: 0.00	Take-off:35.06	Tc:2.5	
Detector Type :SUTW-Sapphire	Resolution :168.00	Lsec :60		
EDAX ZAF Quantification	Standardless			
Element Normalized				
SEC Table : Default				
Element	Wt %	At %		
PbM	2.36	0.74		
CuK	60.83	62.5		
ZnK	36.8	36.76		
Total	100	100		
Element	Net Inte.	Bkgd Inte.	Inte. Error	P/B
PbM	56.92	122.2	3.94	0.47
CuK	3424.83	102.15	0.23	33.53
ZnK	1816.65	90.82	0.32	20